SeaWiFS Lunar Libration Corrections

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Libration effects are changes in the lunar radiance as seen from the spacecraft due to variations in the side of the Moon that faces the Earth during the lunar observations (the libration of the Moon). Once the libration effects have been quantified in the SeaWiFS data, corrections for the effects can be computed and applied to the calibration time series. Commonly, the libration angles are defined to be the selenographic longitude and latitude of the sub-Earth point on the lunar surface. For correcting the lunar calibration time series, the libration angles are defined to be the coordinates of the sub-spacecraft point on the lunar surface. Since the amount of sunlight reflected by the lunar surface is a function of the position of the sun in the lunar sky, the definition of the libration angles is expanded to include the selenographic coordinates of the subsolar points on the lunar surface. Accordingly, the libration effects in the SeaWiFS data are computed from linear regressions of the selenographic longitude and latitude of the sub-spacecraft and sub-solar points against the intermediate lunar calibration time series.

1. Libration Angles

For each lunar calibration, the position of the spacecraft is computed by the SeaWiFS navigation software. The software also generates the ephemeris of the Sun, Earth, and Moon using the low-precision formulas for planetary positions of Van Flandern and Pulkkinen (1979). The positon vectors of the spacecraft with respect to the Moon and of the Sun with respect to the Moon are computed in ecliptic coordinates. A rotation matrix (Escobal, 1965, Methods of Orbit Determination, Transformation 26) converts the position vectors from ecliptic to selenographic coordinates. The coordinates of the sub-spacecraft and sub-solar points on the lunar surface are computed from the position vectors. The time series of the coordinates are shown in the figures *Selenographic Longitude of the Sub-Spacecraft Point*, *Selenographic Latitude of the Sub-Spacecraft Point*, *Selenographic Longitude of the Sub-Solar Point*, and *Selenographic Latitude of the Sub-Spolar Point*. These four sets of coordinates constitute the libration angles for computing the libration effects in the SeaWiFS data.

2. The Libration Correction

The libration effects are computed for each band by performing a multiple linear regression of the lunar time series against the sub-spacecraft and sub-satellite coordinates. The regression fit has the form:

$$(c_0 \; + \; c_1\, l_{sc} \; + \; c_2\, b_{sc} \; + \; c_3\, l_{sun} \; + \; c_4\, b_{sun}) \;\; = \;\; \frac{S_1(t, \lambda, \alpha, \gamma)}{S_1(0, \lambda, \alpha, \gamma)} \qquad (1)$$

where:

c_0 $\equiv$ libration correction constant
c_1 $\equiv$ libration longitude correction coefficient
c_2 $\equiv$ libration latitude correction coefficient
c_3 $\equiv$ libration longitude correction coefficient
c_4 $\equiv$ libration latitude correction coefficient
l_{sc} $\equiv$ longitude of the sub-spacecraft point
b_{sc} $\equiv$ latitude of the sub-spacecraft point
l_{sun} $\equiv$ longitude of the sub-solar point
b_{sun} $\equiv$ latitude of the sub-solar point

The libration corrections are the inverse of the libration effects:

$$f_5(l_{sc}, b_{sc}, l_{sun}, b_{sun}) \;=\; (c_0 \;+\; c_1\, l_{sc} \;+\; c_2\, b_{sc} \;+\; c_3\, l_{sun} \;+\; c_4\, b_{sun})^{-1} \tag{2}$$

The libration corrections should have a minimal wavelength dependence, if any. However, the linear regression approach to computing the libration effectss breaks down for bands where the change in the radiometric reponse of the instrument with time is comparable in magnitude to the libration effects. Such conditions occur for bands 7 and 8. In order to obtain the most accurate libration corrections possible the libration effects for bands 4 and 5, which have the smallest change with time, are averaged on a calibration-by-calibration basis. These mean libration effects are shown in the figure *SeaWiFS Lunar Libration Effects*. The libration corrections, the inverse of these mean libration effects, are applied to all eight bands for the lunar calibration time series analysis.